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ABSTRACT

This study was undertaken to determine whether neo-Piagetian theory might provide a functional interpretation of children's motor development, particularly linear positioning. In addition, intra-age and inter-age comparisons for both high- and low-mental-processing children were made. Pascual-Leone's Figural Intersection Test was used to select 15 high- and 15 low-mental-processing children from three public elementary schools. A linear-positioning test served as the criterion-referenced test and was defined as a multi-scheme task involving the repositioning of a pointer at the mid-position between any two of the three, four, or five completed movements along an arc of 225 degrees. Data were compared for six- and eight-year-olds on a three-scheme task, and eight- and ten-year-olds on a four-scheme task. Results indicated support for an age-related linear increase in mental processing across three dependent measures. This development appeared to be a maturational phenomenon occuring without the benefit of practice. The results also appeared to affirm that high mental processors of one age level would perform as well as or better than low mental processors of the next higher age level. It was noticed that the lower level of motor task performance than might be predicted by neo-Piagetian theory may well be due to the different focus of traditional (cognitive) developmental tasks and the present (motor task) study. The findings indicate that a child's mental space might be an important determinant of success or failure of those motor acts that require the activation and integration of considerable motor information. (MJB)

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A Developmental Assessment of Motor Performance in High M-Processing and Low M-Processing Children

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A Developmental Assessment of Motor Performance in High M-Processing and Low M-Processing Children

During the past few years, there has been a noticeable change in the way many researchers in the area of motor behaviour have approached their problems. Instead of the more traditional independent variable effect analysis, investigators have begun to examine the kinds of processes which underlie motor behaviour and to delineate the events that enable the individual to perform or learn a motor task. Schmidt (1975) adroitly points out that a part of the reason for this shift in emphasis has been the inadequacy of traditional theories to provide a reasonable explanation for motor performance. Within the last decade, there has been more reliance on control and communication approaches to describe the nature of motor skill behaviour, as witnessed by the efforts of Adams (1968, 1971), Schmidt (1975) and Smith (1972) in cybernetic and closed-loop control approaches, and Welford (1968) and Pew (1974) in information processing.

Notwithstanding these advancements, contemporary process-orientated theorists have demonstrated a general lack of concern for developmental considerations, i.e., the control and communication models do not adequately account for the way in which the processes are developed within the child. What kinds

of changes take place in the child that enables him to perform progressively more complex motor tasks? Moreover, can such changes be predicted in order to rationally account for specific motor behaviour at a particular chronological level?

The present work focuses on the application and empirical assessment of neo-Piagetian theory as a process-orientated explanation and predictor of the development of a motor skill in young children. Contention is offered that this formulation may account, not only for the temporal sequence of development, but also for the functional mechanisms by which motor learning and development occurs, thus extending the bounds of the more structural Piagetian model.

Pascual-Leone (1970) and Pascual-Leone and Smith (1969) have introduced a neo-Piagetian model which combines Piaget's powerful notion of general stages with a quantitative parameter to explain what occurs in the child's cognitive make-up (with incresed age) to cause him/her to move through the Piagetian stages. In revising the original model, Pascual-Leone has furnished an information processing scale to explain why the child can or cannot contend with the typical Piagetian tasks.

According to neo-Piagetian theory, a child's psychological system can be described by two components: (a) a repertoire of behavioural units of schemes, and (b) a central computing

space (mental-space or M-space) in which the information from the repertoire is integrated or transformed to meet the demands of the environment.

The central notion of the scheme has been described as an organized set of reactions capable of being transferred from one situation to another by assimilation of the second to the first (Piaget & Morf, 1958) and as the subjective units of thought which function like a set of mental blueprints (Case, 1974).

Two forms of M-space have been postulated: structural (M_s-space) and functional (M_f-space). M_s-space is seen as the maximum numbers of schemes that the child can attend to or integrate in a single act and is quantitatively defined as a + k, where a is an unknown but constant across-ages component corresponding to the processing space occupied by the mental strategy; and k, an age-related linear numerical representation of the number of schemes which can be simultaneously and/or serially coordinated during a single act. As shown in Table 1, the neo-Piagetian scale of development provides a quantitative M_s-space value for the Piagetian general stages.

Insert Table 1 about here

Numerous studies (e.g. Case, 1972a, 1972b, 1974; Gerson & Thomas, 1977; Pascual-Leone, 1970; Pascual-Leone & Smith,

1969) have provided support to the validity of the M-space construct. As would be expected for any behavioural construct, there is variability about the assigned a + k value. This intra-group variance is best explained by the functional M-space (M_f-space): that portion of the M_s-space which the child actually utilizes at a given moment. The assumption prevails (e.g. Case, 1974) that children can be classified as high or low M-processors based on their tendency/ability to use that portion of the M_s-space needed in meeting the particular demands of the task. Low M-processing children tend to respond to tasks with the least amount of mental effort, generally displaying an M_f-space below their chronological developmental capacity of M_s-space. High M-processors, on the other hand, exert the mental effort needed to cope with the task, their M_f-space being equal to, or exceeding the assigned theoretical M_s-space value.

The individual differences described by M-space utilization may provide a framework within which to analyze both intra- and intergroup variability of children's motor skill behaviour. Some empirical data are available which give evidence that children of different ages use different abilities to perform the same task (Cumbee, 1954; Goodenough & Smart, 1935). Tudor (1973) suggested that as a child grows, different types of abilities come into prominence, which in turn give way

to others as growth proceeds, a position which seems compatible with the neo-Piagetian age-related increases in the number and complexity of schemes.

The appropriateness of a child's motor response may be a function of the schemes available (experience) and the M-space necessary to coordinate them. The increase in specificity of performance with increased age (Carron, 1971; Henry & Nelson, 1956; Thomas & Chissom, 1962) suggests that performance differences may be related to the variability in M-space available and the repertoire of schemes. Mitchell and Thomas (1976) reported that preoperational children lacked the ability to use precise kr with a difficult angle in a repositioning task, but as subjects at the concrete stage improved performance through the utilization of the precise kr these differences were seen as a function M-space variability.

Based upon the premise that neo-Piagetian theory may provide a functional interpretation of children's motor development, the present study was undertaken to test this theory as an explanation of one aspect of motor behaviour, linear positioning. In addition, the design of the present investigation included provisions for intra-age and inter-age comparisons for both high M-processing and low M-processing children. It was hypothesized that within a particular age group, high M-processors would perform significantly better than low M-processors

on a task requiring the predicted (a + k) neo-Piagetian level of processing. Further, the existence of a behavioural overlap between high M-processors of one stage and low M-processors of an adjacent higher age group was hypothesized, this being founded on the prediction that high and low M-processing ability would be expressed by a + k + 1 and a + k - 1 functioning, respectively.

Method

Subjects

The subjects were selected from three public elementary schools in Tallahassee, Florida. A total of 269 6-year-old, 8-year-old and 10-year-old males were administered a revised version of Pascual-Leone's Figural Intersection Test (FIT) (Thomas & Bender, 1977). The study sample selected on the basis of their scores on the FIT consisted of 15 high M-processors (HMP) and 15 low M-processors (LMP) from each of the three age levels. Based on the FIT scores, high M-processors were operationally defined as one SD above their age group mean while low M-processors were one SD below their age group mean. In one instance, LMP 8-year-old group, only 13 subjects were delineated by the FIT screening phase. Two subjects were added whose FIT scores closely approximated the established criteria. In all cases, the most extreme FIT scores were chosen for sample selection.

Instruments

The FIT was used as the pre-selective measure to determine the subjects for testing on the criterion task. The FIT is a paper and pencil test consisting of geometric shapes superimposed on one another. The child's task is to first acknowledge the geometric shapes shown separately on the right side of the stage, and then place a pen dot in the corresponding figure on the left side at the space where all the spaces intersect. Scores are calculated as the aggregate of the total number of shapes in each figure in which the child determines the correct intersection point.

A linear positioning task (LPT), first developed by Thomas and Bender (1977), served as the criterion task. The task consists of a raised wooden platform (66 cm x 76 cm) upon which is inscribed an arc of 225°, and a moveable metal pointer which could be moved over the arc. The arc is divided into 15 equal parts of 15°. A small curtain blocking the subject's view of the apparatus is affixed to the front. A point of 25° below the horizontal was used as the start for each positioning movement.

Procedure

The subject was instructed to move the pointer until it was stopped by a metal peg placed in its path by the investigator. After a 1-second delay at the stop, the subject returned the pointer to the start position. The next movement required

the subject to move the pointer to a second stop located 10° beyond the initial stop. Again, after a 1-second delay at the stop, the subject returned the pointer to the start position. The subject was then asked to move the pointer to the mid-point between the two original stops.

This was defined as a two-scheme task: two stop points with a repositioning at their mid-point. The 3-, 4- and 5-scheme tasks were handled in a similar fashion requiring the subject to reposition the pointer at the mid-point between any two of the three, four, or five completed movements respectively.

A trial consisted of moving the pointer to the stop points and then repositioning it at the mid-point between the appropriate two positions. A total of 10 positioning trials was administered for each subject for each level of scheme activation. The 6-year-old subjects were tested for 2- and 3-scheme ability, the 8-year-olds for 3- and 4-scheme ability and the 10-year-olds for 4- and 5-scheme ability. In all cases, the initial stop was randomized while the increments for succeeding schemes was 30° beyond the previous stopping point. The subject received a score for the number of correct repositioning responses (defined as placing the pointer anywhere between the original end points of the two schemes). In addition, constant error (CE) and variable error (VE) were calculated utilizing the exact mid-point as the zero-error point.

Results

The data were subjected to a 3 x 2 factorial (age groups x processing ability) multivariate analysis of variance. Descriptive statistics for each of the dependent variables (correct score CE and VE) are presented in Table 2.

Insert Table 2 about here

The multivariate procedures revealed a significant main effect for processing ability, F (1,34) = 34.84, $p < .01$, while the age effect and interaction were non-significant. A stepwise discriminant analysis indicated that correct score was the strongest discriminator for the processing effect $F(1,88)$ = 78.37, $p < .01$, while to a lesser degree VE was also demonstrated to have significant discriminating power $F(1,87)$ = 10.82, $p < .01$. These data indicated that the three age groups did not differ in performance on their a + k task, while marked performance differences were evident between the HMP and LMP groups.

Comparison of the 6-year-old and 8-year-old on the 3-scheme task

A 2 x 2 (age x processing ability) factorial MANOVA indicated significant main effects for age, $F(3,54)$ = 13.09, $p < .01$ and for processing ability $F(3,54)$ = 13.09, $p < .01$ for the 6-year-old and 8-year-old groups on the 3-scheme task. The stepwise discriminant analysis on the main effect of age indicated that correct score held significant discriminatory $F(1,58)$ =

18.13, $p < .01$, while the indices of VE and CE did not meaningfully differentiate performance across the two age groups. It is interesting to note that the univariate F value for VE was significant, F (1,58) = 4.50, $p < .05$, but that step-down F procedures clearly indicated that the magnitude of this value was due to the considerable variance shared between the measures of VE and correct score. The stepwise discriminant analysis for the main effect of processing ability revealed the correct score to be the most powerful discriminator F (1,58) = 25.70, $p < .01$, while VE was also shown to be significant F (1,57) = 5.67, $p < .01$. A further stepwise discriminant analysis revealed no significant differences between the 6-year-old HMP and the 8-year-old LMP performance on the 3-scheme task indicating the existence of a behavioural overlap.

Comparison of the 8-year-old and 10-year-old groups on the 4-scheme task

A 2 x 2 factorial MANOVA (age x processing ability) showed the main effects of age F (3,54) = 7.66, $p < .01$, and processing F (3,54) = 30.16, $p < .01$, both to be significant. Rather unexpectedly, the age x processing interaction was also shown to be significant, F (3,59) = 3.50, $p < .05$.

Stepwise discriminant analysis for the main effect of age indicated that correct score was the strongest discriminator of the three measures, F (1,58) = 9.83, $p < .01$, while a similar analysis conducted on the main effect of processing ability

revealed that VE was the best discriminator F (1,58) = 53.99, $p < .01$.

Independent ANOVA's were performed for each of the dependent variables to examine the significant age x processing interaction effect. A significant unvariate age x processing interaction effect was evident only for the correct score dependent variable F (1,56) = 8.59, $p < .01$. An examination of the VE means precludes any notion that the LMP 10-year-old might have had a number of near misses. Rather, it appears that the interaction was due to the unexpected poor performance of the LMP 10-year-olds on their a + k task, one in which they scored only about .5 more correct on the average (2.46 vs 1.93) than the LMP 8-year-olds.

A stepwise discriminant analysis indicated the HMP 8-year-olds had significantly lower VE scores than the LMP 10-year-old group, F (1,28) = 28.40, p .01, demonstrating an overlap of performance.

Within age group comparisons

Performance comparisons were made between the high and low M-processors within each age group for their a + k and a + k + 1 tasks. Stepwise discriminant analyses revealed that the HMP 8-year-olds had significantly less VE than their LMP counterparts for both the 2-scheme task, F (1,27) = 16.57, $p <$ .01, and the 3-scheme task, F (1,27) = 4.28, $p < .01$. The HMP 8-year-old had significantly more correct responses than their

LMP group for the 3-scheme task F (1,28) = 28.56, $p < .01$, and had significantly less VE on the 4-scheme task F (1,28) = 17.27, $p < .01$. Similar findings were evident for the 10-year-old groups. For the 4-scheme tasks, HMP 10-year-olds had significantly more correct responses than their LMP counterparts, F (1,28) = 46.16, $p < .01$, and with it demonstrated a smaller VE, F (1,27) = 12.80, $p < .01$. On the a + k + 1, or 5-scheme task, the HMP once again was superior in performance to the LMP group, demonstrating a smaller VE, F (1,28) = 14.57, $p < .01$.

Discussion

Results indicated support for an age-related linear increase in M_s-space; this being consistent with previous findings conducted in the cognitive domain (e.g. Case, 1972a; Pascual-Leone, 1969) and in the psychomotor domain (Thomas & Bender, 1977; Tudor, 1973). Noteworthy is the fact that the present results reveal this trend across three dependent measures. In addition to the index of correct score (the measure most frequently used in neo-Piagetian investigations), results indicated that the relative accuracy (CE) and variability (VE) of the linear positioning task performance remained fairly consistent across age as the task complexity was increased, providing evidence of a linear increase in the parameter of k.

This development M -space appears to be a maturational phenomenon whose sudden appearance occurs without the benefit of practice. Within such a context the "all-or-none" growth

of M_s-space, phonomenologically analogous to nerve impulse conduction, is viewed as a discrete change on the amount of information which can be integrated in a single act. The likelihood that M_s-space occurs in a law-like fashion free of environmental effect may be aligned with earlier findings that fundamental motor patterns transcend physical restrictions (Denis, 1940) and training (Gesell & Thompson, 1929).

The present study affirms the notions that high M-processors of one age level would perform as well, or better than, low M-processors of the next higher age level, demonstrating the existence of a behavioural overlap. Quantitatively this overlap has been described by a range in M-space ability which varies from a + k + 1 for extreme low M-processors to a + k + 2 for the high M-processors: this M_f-space variability setting apart neo-Piagetian theory from the more structured traditional Piagetian model of development.

The level of M_f-space in the child may be influenced by his level of maturation and/or particular cognitive-perceptual style. While it has been contended that some high M-processors perform at a level beyond their assigned theoretical capacity by reducing the M-demand of the task through the process of L-learning (Case, 1976), this does not seem to be the case for the present study. The novel task demands did not allow sufficient time for this type of process to occur. More likely, high M-processors possessed a more advanced level of M-space maturation than their peers. The low M-processor might be

characterized by a particular cognitive-perceptual style in which the individual responds in a simple manner with a set of operations involving the least possible mental effort. This type of perceptual behaviours has been related to the cognitive style dimension of field dependence-field independence (Case & Globerson, 1974; Pascual-Leone, 1969). Empirical data are available which indicate a behavioural overlap in the performance of 6-year-old field-independent subjects and 8-year-old field-dependent subjects on both a cognitive and a motor 3-scheme task (Thomas & Bender, 1977).

The results of six within-group comparisons showed that high M-processors performed significantly better than low M-processors of similar age in both the a + k and a + k + l tasks. For each comparison, the results indicated that the processor groups were significantly differentiated when correct score and/or VE were used as dependent measures. Constant error was not a meaningful discriminatory processing ability. While it appears that VE and correct score related (i.e., the greater number of correct scores) the greater likelihood of a small VE, each represents a different type of measure. Correct score represented a measure of the respondent Ms ability to activate and integrate previous information while VE provided knowledge about the across-trial variability of the subject's performance. In four of the six comparisons, VE was shown to be the best within-group discriminator. Moreover, VE held the greatest discriminatory power in each of the a + k + l tasks, suggesting that for difficult tasks the child's processing

ability was less differentiated by his correct score response than by the size of his repositioning error. The need for VE as a measure seems particularly appropriate for experimentation which involves precision of movement.

Inasmuch as neo-Piagetian theory was developed within the cognitive domain, some concluding remarks seem warranted vis-a-vis its viability as a means to explain the predict motor behaviour in young children. Perusal of the means for the correct score variable on the a + k task indicates that performance was somewhat lower than might have been predicted by the neo-Piagetian theory of development. For example, high M-processors repositioned correctly only about 6 in 10 times, a far lower success rate than that reported when using a similar task in a more cognitively-orientated manner (Thomas & Bender, 1977).

The most cogent explanation for these differences focuses on the fundamental differences between the two types of tasks in question, the proprioceptive processes required in responding motorically being less precise in nature than those involved in the structuring and recall of a series of numbers (Case, 1972b). The activation and integration of proprioceptive data appears to be a more difficult process than the recall of purely cognitive data, the result being a general lowering of correct score performance in respect to neo-Piagetian predictions. The extent of this decrement is far less clear. An inspection of the data indicates that the parameter k is reduced

by a value of 1 from that level posited in the theory.

Insert Figure 1 about here

A model of neo-Piagetian motor learning and development is presented which incorporates a contemporary motor schema approach previously forwarded by Schmidt (1975). Inclusion of Schmidt's features is based on the need to adequately account for performance processes such as sensory feedback which are of paramount import to a description of motor learning. The two types of feedback loops reflect the post-movement consequences. The appropriate action is looped directly back to the child's repertoire of schemes while an incorrect response may be assimilated or accommodated. The young child who possesses relatively egocentric tendencies may assimilate the outcome and bend it to fit the existing representation of what the outcome should be. In contrast, other children, particularly those who have a relatively high M_f-space, may accommodate, altering their existing structure to see the environmental demands. This change is accomplished through practice which operatively transforms the existing schema.

In summary, the findings of this study indicate that a child's M_f-space might be an important determinant of success or failure of those motor acts which require the activation and integration of considerable motoric information. Neo-Piagetian theory may offer a viable means to predict and explain motor development and performance, particularly through the

integration of specific motor schema constructs.

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Table 1

M-space Development in neo-Piagetian Theory

Developmental sub-stage	Age	M_s-space (a + k)
Early pre-operational	3 - 4	a + 1
Late pre-operational	5 - 6	a + 2
Early concrete	7 - 8	a + 3
Late concrete	9 - 10	a + 4
Early formal	11 - 12	a + 5
Middle formal	13 - 14	a + 6
Late formal	15 - 16	a + 7

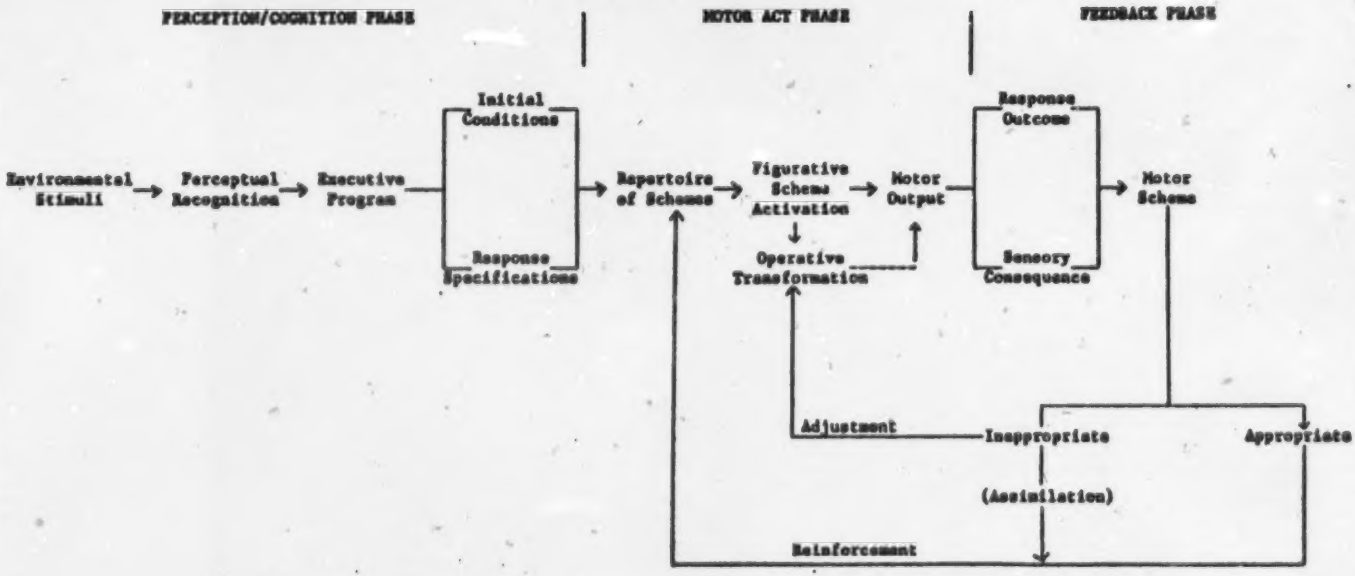
Table 2

Descriptive LPT Data for the Study Groups

Group	N	Age (Mos.)	Variable	SCHEME 2 $\bar{X}$	2 SD	2 $s\bar{x}$	3 $\bar{X}$	3 SD	3 $s\bar{x}$	4 $\bar{X}$	4 SD	4 $s\bar{x}$	5 $\bar{X}$	5 SD	5 $s\bar{x}$
HMP 6	15	77.3	Correct	5.86	2.06	0.53	3.33	1.55	0.40						
			CE	-93.40	109.14	28.18	-101.66	141.69	36.58						
			VE	14.38	5.19	1.34	19.87	4.51	1.16						
LMP 6	15	79.4	Correct	3.46	1.45	0.37	1.80	1.14	0.30						
			CE	-34.80	140.72	36.33	25.73	129.73	33.49						
			VE	24.36	7.93	2.05	30.08	7.25	1.87						
HMP 8	15	106.3	Correct				6.00	1.65	0.42	3.47	1.25	0.32			
			CE				-69.93	124.35	32.10	-129.46	99.18	25.60			
			VE				17.83	11.67	3.01	19.88	5.53	0.91			
LMP 8	15	104.6	Correct				3.26	1.09	0.28	1.93	1.03	0.27			
			CE				-83.93	178.64	46.12	-64.73	174.60	45.08			
			VE				22.61	5.92	1.52	26.41	6.06	1.56			
HMP 10	15	123.7	Correct							5.93	1.53	0.39	3.53	1.45	0.37
			CE							-94.00	75.63	19.52	-159.73	105.34	27.19
			VE							5.31	3.89	1.00	18.77	5.05	1.30
LMP 10	15	127.5	Correct							2.46	1.25	0.32	1.73	1.33	0.34
			CE							-121.53	118.33	30.55	-162.06	91.76	23.69
			VE							27.70	6.40	1.67	28.14	8.01	2.07

Figure Caption

Figure 1. Neo-Piagetian motor scheme.


PERCEPTION/COGNITION PHASE
MOTOR ACT PHASE
FEEDBACK PHASE
Environmental Stimuli
Perceptual Recognition
Executive Program
Initial Conditions
Response Specifications
Repertoire of Schemes
Figurative Schema Activation
Operative Transformation
Motor Output
Response Outcome
Sensory Consequence
Motor Scheme
Adjustment
Inappropriate
Appropriate
(Assimilation)
Reinforcement